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Schrøder, Lise

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MULTIDIMENSIONAL BUILDING OBJECTS IN A DANISH GEO-INFORMATION INFRASTRUCTURE PERSPECTIVE

Lise Schröder

Aalborg University, Department of Development and Planning
GIM - Laboratory of GeoInformation and Media Technology
Denmark

ABSTRACT

The emerging multidimensional GI- and VR-technologies within the professional disciplines dealing with design, planning and management processes is leading to a demand for four-dimensional building objects as part of the public geo-information infrastructure. The other way around the recognition of the building as a four-dimensional geo-phenomenon will provide a reference between different data sets whether representing buildings in two, three or four dimensions. Finally a central issue is the potential in using frameworks of multidimensional representations as interfaces to the available data sets.

A Danish core data set based on three-dimensional building objects as well as aspects of time is suggested as means of facilitating the co-ordination of the object definitions in the existing public and private 2D-map products, the public registers as well as the 3D-concepts from the built and planning environments. On this basis the interaction between actual use, the structuring paradigm, the means of communication as well as the actual need for metadata and metainformation in a city-renewal environment is considered.

1. INTRODUCTION

Along with the extended use of spatial information technology and the Internet Danish public maps and registers originally defined for specific tasks related to physical planning, taxation of buildings or statistics concerning housing et cetera become of more general interest.
Data related to buildings represent a very large potential. As privates or professionals we are all users of information related to buildings and a wide range of other data sets have references to these objects.

Within the built environment, city planning or city management specialised training, practises and tools have defined specific ways of understanding as well as handling information related to buildings. Though efforts have been made to establish procedures supporting sharing and exchange of building data, consensus concerning object definitions has still not been achieved. This is related to the paradox that despite the extended use of CAD and IT in general among the professional parties involved in designing buildings most of the following information exchange procedures are still based on paper documents and 2D-drawings. Similarly the primary part of analysis done by city planners in the Danish municipalities are

still conducted on paper maps though GI-technology is available elsewhere in the organisation. Redundant databases and lack of efficiency considering data maintenance procedures are among others obvious results.

This paper focuses on modelling multidimensional building objects as means of bridging the cognition gabs amongst different users of data related to buildings regarding professionals dealing with disciplines within the built environment, city planning or city management as well as unskilled users of geodata-services. Those matters are central issues of a Ph.D.-project concerning data quality aspects related to exploiting the potential in increasing use and reuse of public as well as commercial or private data sets concerning buildings. The Ph.D.-project is closely related to two interdisciplinary Danish research initiatives respectively the Danish spatial infrastructure project ISI and the 3DGI-project also dealing with matters related to making geodata understandable and shareable regarding purpose as well as user qualifications.

2. BACKGROUND

In Denmark there are old traditions of registering and mapping for different purposes and especially during the last three decades a wide range of national maps and registers have been established due to the various tasks of the increasing public sector and the need for regulation and taxation.

Most of those Danish national maps and registers have now been converted to a digital form and steps have been taken to standardise and reorganise public databases and loosen up legislation to full-fill government intentions of supporting the information society. Unique keys and geo-references based on standardised addresses linking a wide range of administrative databases have gradually been established as well as an Internet based metadata service (Geodata-info) according to the CEN standard. The first version of the public information server (OIS) providing attribute data from the public property registers (fig. 1) was launched in august 2001 and will be extended to include maps as well.
Though to co-ordinate efforts among public authorities, private enterprises as well as academic institutions more attention concerning formalising Danish geo-information infrastructures will be needed *(Brande-Lavridsen et al., 2001)*.

2.1. Infrastructure for Spatial Information

Based on the on-going projects handling different infra-structural matters related to the Danish geo-information society the research initiative Infrastructure for Spatial Information (ISI) was formulated in 1999-2000 in co-operation between researchers from The National Survey and Cadastre (KMS), The Copenhagen Business School and Aalborg University *(Brande-Lavridsen et al., 2000)*.

National Spatial Data Infrastructures (NSDI's) have been developed with varying scopes in different countries. As defined by ISI the Danish spatial data infrastructure concerns the technologies, politics, rules and human resources necessary to achieve a socio-economically effective use of spatial information at all levels in society *(Brande-Lavridsen et al., 2001).*

So far the research projects directly related to the ISI initiative has been concentrated about four themes:

The Geographic Information Market - concerning commercial aspects regarding digital spatial data is carried out at The Copenhagen Business School.
Spatial Data Modelling and Cataloguing - dealing with methods to restructure spatial data from maps and registers into object-oriented catalogues and spatial data models is carried out at the The National Survey and Cadastre as well as Aalborg University.
Distributed Geographic Information Prototype - further research at Aalborg University where the goal is to produce an experimental web service based on the resulting object catalogues and spatial data models developed in the above mentioned project.
Visualisation of Spatial Information in Electronic Media - research at Aalborg University intending to enhance visualisation and optimise the understanding of geographic information.
The primary goal of the ISI-project has been to support the further development of a formal Danish NSDI, though it has been emphasised that to ensure co-ordinated efforts within this field a legal mandate would be preferable *(Brande-Lavridsen et al., 2002*).

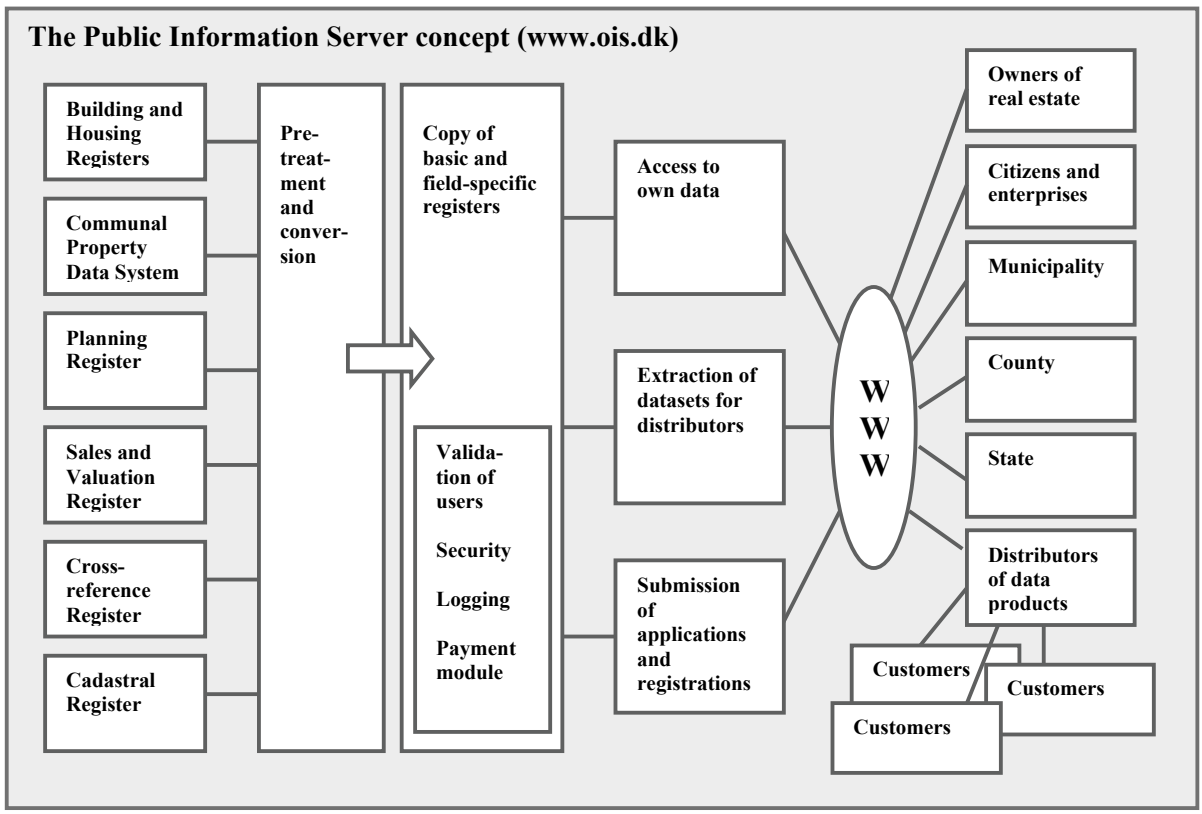

Figure1: The OIS Concept - step 1.

Another interdisciplinary research project at Aalborg University concerning 3D-geoinformation (3DGI) are closely related to infra-structural matters. The 3DGI-project is situated at the VR Media Lab at Aalborg University and a central issue is to develop a Virtual Geographic Infrastructure (VGI) based on VR- and GI- technology. The VGI is conceptualised by creating a 3D-model of the northern region of Jutland to be used as interface to diverse urban and rural information within local and regional planning, marketing and public service et cetera. The project is supported by the European Development Fund and is carried out in corporation with the National Survey and Cadastre (KMS) as well as private companies *(Munk Sörensen, 2001)*. The potential in using 3DGI-interfaces as means of exploring various datasets related to the public information server (OIS) launched 2001 by the

former Ministry of Housing and Urban Affairs as well as the emerging concepts of 3D-multipurpose Cadasters are central infra-structural issues related to the 3DGI-project.

2.2. Geodata Service Community

As suggested by a government taskforce report in January 2002 a service community concerning geodata has recently been established in order to support the visions of digital management at al levels within the Danish public administration. It is pointed out that legal aspects concerning ownership and responsibility due to conflicting interest among private enterprises as well as public authorities are blocking the achievement of a shared strategic view, and the importance of co-ordinating infra-structural matters regarding geodata is emphasised *(Den Digitale Taskforce, 2002)*.

The board of the service community is lead by the Ministry of Environment and counts representatives from the Ministry of Economic and Business Affairs, the Ministry of Food, Agriculture and Fisheries as well as representatives from the national organisations of respectively the municipalities and the counties. Though the importance of private and public owners, producers and users of geodata et cetera joining the geodata community as well is emphasised *(Den Digitale Taskforce, 2002)*.

In a primary draft is underlined that the challenge is to ensure benefits of the major investments in digital maps, geo-referenced addresses and distribution systems by facilitating the digital administration project and increasing geodata usability among private as well as public parties. To meet this challenge a primary goal of the geodata service community is to develop a visionary and strategic framework concerning geodata infrastructure issues as data, data access, data models, prising et cetera to promote corporation across organisational borders and at al levels *(Geoforum, 2002)*.

3. INFRASTRUCTURAL INITIATIVES REGARDING BUILDINGS

Of key interest considering multiple use of Danish building data is the national Building and Dwelling Register (BBR) and the efforts made to establish the CIS-CAD-structure as means of rationalising information flows during the processes concerning designing, permitting or managing buildings as well as maintaining the relevant databases. Of great relevance are also the experiences from the Common Object Type project (FOT) where measures have been taken trying to co-ordinate the object definitions in the municipal technical maps (TK) and the national topographic map TOP10DK.

3.1 The Building and Dwelling Register

The Building and Dwelling Register (BBR) is an object oriented administrative register established in 1977 to provide information for statistics and taxation purposes. In the BBR specific information concerning all buildings in Denmark are stored and the register is considered of great potential as a multi-purpose register *(Kort- og matrikelstyrelsen, 2000)* including unique (preliminary) geo-referenced entrance-door addresses functioning as the primary key to Danish administrative databases *(Kort- og matrikelstyrelsen, 2002-1)*.

The three levels of registrations are still relating respectively to property, building and unit. Though the development of the Logical Data Model (LDM) concerning Danish property data

(Kort- og Matrikelstyrelsen, 1998) as well as the address-project *(Lind, 2000)* is based on a suggested revision (fig. 2) of the BBR *(Kort- og Matrikelstyrelsen, 1996)*.

The BBR register contains specifications of the actual use, building materials, installations, and year of construction as well as year of re-construction or demolition. Calculations of areas due to various administrative purposes as well of the number of stories are registered *(Kort- og Matrikelstyrelsen, 2002-2)*. Though it lacks precise height information and regarding 3D-modelling of buildings in general, the register is poorly suited due to the lack of graphical information.

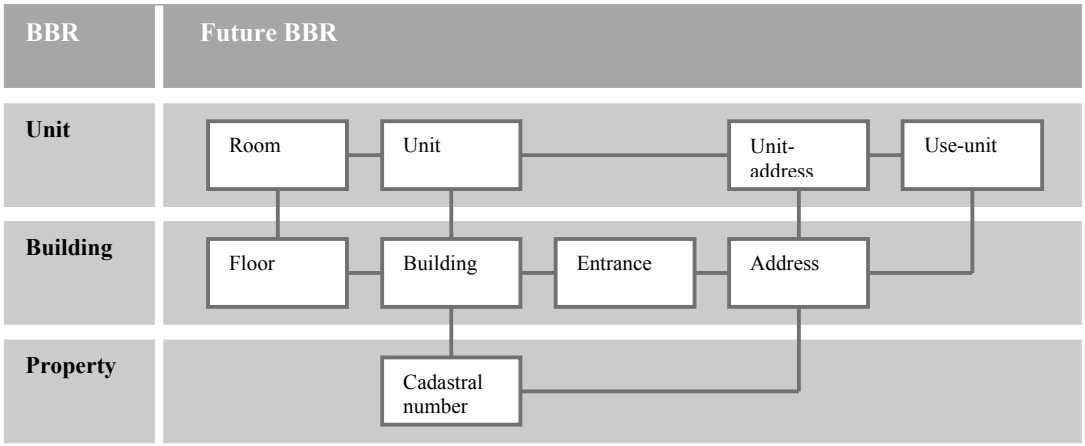

Figure 2: BBR registration and address levels.

For the time being inefficient updating procedures as well as lack of consistency between the buildings registered in respectively the BBR and the technical as well as topographic maps are the main data quality aspects to be considered *(Daugbjerg et al., 2000)*. Though a revised definition of the BBR building object trying to harmonise definitions among building objects in maps, registers as well as project-data *(Kort- og Matrikelstyrelsen, 1997)* has still not been implemented. Regarding the updating procedures a central problem is that the owner is responsible for informing the authorities when a building undergoes changes, and especially the conflicting interests due to changes that affects the taxation which typically increases *(Kort- og Matrikelstyrelsen, 2001)*.

3.2 The Common Object Type project

The national topographic map TOP10DK is a commercial product from the National Survey and Cadastre while the technical maps (TK) in various scales is owned and maintained by the municipalities. The Common Object Type project (FOT) defined in corporation between the National Survey and Cadastre, municipal as well as county authorities, utility owners and the former Ministry of Environment and Energy is an attempt to co-ordinate efforts regarding the TK and the TOP10DK map products. Due to the potential in data-sharing, rationalising updating procedures as well as avoiding redundant data especially the building object has been considered of great importance *(FOT, 1999)*.

A central issue concerning the lack of consistency between the two map products considering object geometry definitions as well as level of detail especially regarding urban areas has caused quite a lot of resistance among the actual users. In TOP10DK the representation of the building is based only on the orthogonal projection of the roof while also the shape of the

ground floor plan is represented in the technical maps. Furthermore the level of detail as well as the type of buildings represented varies due to the different purposes and scales. Finally a central issue is that for the time being only a few municipalities has separated and geo-coded their TK-buildings due to the BBR-definition. Though a case-study concerning two urban municipalities carried out by the National Survey and Cadastre concludes that if the TK-building is geo-coded, it will be possible to select the relevant TK-buildings via their use-code in the BBR and generalise objects from the TK to the TOP10DK. Comparative generalisations from data sets based on respectively the ground floor plan and the roof-projection showed very little difference regarding the quality of the resulting generalised objects *(Kort- og Matrikelstyrelsen, 2001)*.

The final report from the FOT-group concludes that despite the resistance against the FOT-concept data-sharing as well as the move towards establishing a general multipurpose map product is an essential issue due to the goal of digital public administration. Though FOT-buildings as a common geometric definition is not possible to achieve at the moment as al kinds of buildings and the existing level of detail has to be represented in the TK, while secondary buildings as garages et cetera has to be left out in the TOP10DK *(FOT, 2001)*.

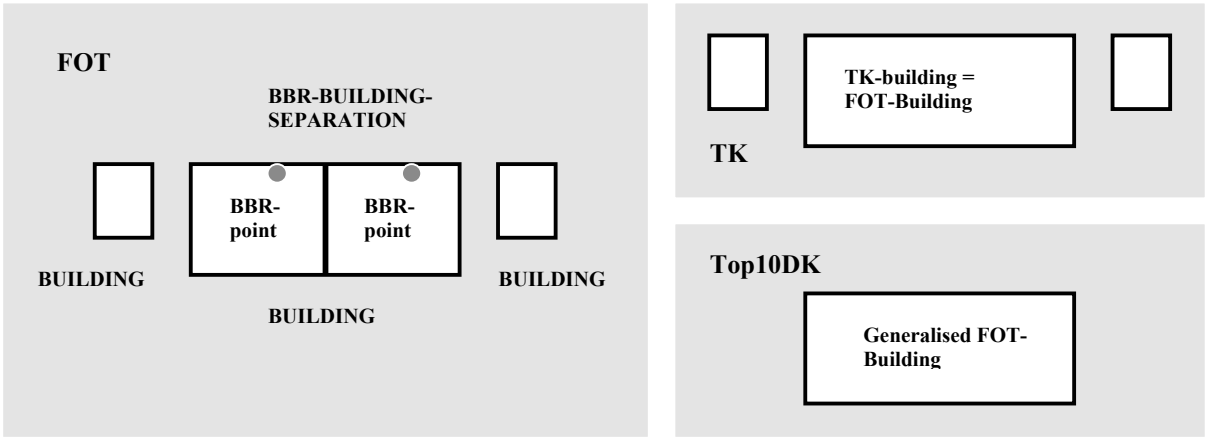

Figure 3: The FOT concept.

Finally it is underlined that BBR-revision proposal from 1997 *(Kort- og Matrikelstyrelsen, 1997)* ought to be further developed and implemented, as well as the BBR-manual has to be made very clear and illustrative to ensure homogenous registrations in the BBR *(FOT, 2001)*.

3.3. The CIS-CAD concept

In order to facilitate systematically re-use of project data from the built environment and increase efficiency as well as data quality the CIS-CAD concept provides a structure and a set of rules concerning the exchange of these data. The attempt is to supplying the municipality with basic data fit for updating registers and technical maps as well as preparing the building owners facilities management systems or GI-databases belonging to supplying companies *(By- og Boligministeriet, 2000)*.

The CIS-CAD concept is based on an object-oriented approach and specifies different groups of data serving administrative purposes as the above mentioned, specific technical matters concerning building parts as well as different instruction purposes. Considering administrative data six entity levels (property, cadastral unit, building, floor, room, use unit) corresponding

with the concept of the LDM provides a consistent framework for exchanging this information *(By- og Boligministeriet, 2000)*.

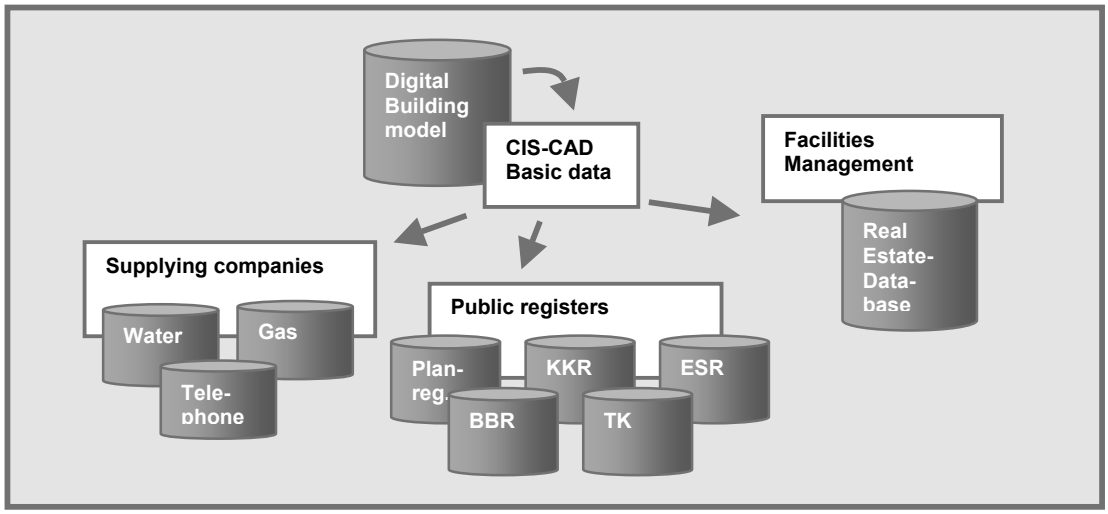

Figure 4: The CIS-CAD concept.

3.4. The built environment

For the time being there are only a few examples of CIS-CAD-implementations. Furthermore a working group established by the Ministry of Economic and Business Affairs concludes that in general the efforts made to facilitate exchange and reuse within the built environment has been quite ineffective due to lack of co-ordination. Though among architect and engineering companies the investment in IT has increased remarkably during the past few years *(Erhvervsministeriet, 2001)*.

The Danish Built environment is very fragmented due to a lot of small enterprises as well as unorganised unprofessional clients. Individual interests due to various professions, interests as well as IT-skills are barriers for achieving a shared strategic view. And compared to especially the car industry the potential in rationalising design and construction processes is far from being reached. Therefore an infrastructural framework supporting the vision of virtual buildings in a digital Danish built environment based on an object-oriented approach and international standards has to be established *(Erhvervsministeriet, 2001)*.

3.5. User needs concerning building data

Related to the ISI-theme *Spatial Data Modelling and Cataloguing* a Ph.D.-project concerning building data, quality aspects and user needs has been formulated. Based on the ongoing initiatives concerning making data sets accessible and usable via co-ordination and standardisation at the national, European as well as global levels the Ph.D.-project is focussing object definitions, data structuring and metadata aspects. Though emphasising the demands regarding users with different views, intents and skills due to a Danish urban renewal context.

City renewal scenarios based on the potential in integrating multidimensional representations of geo-phenomenons *(Raper, 2000)* in complex information systems for urban planning *(Laurini, 2001)* are used as framework for analysing user needs regarding the structure and content of Danish public building data and metadata related to buildings.

Means of documentation, communication and collaboration are the key issue. As means of documentation, communication and collaboration regarding building data and contexts in which they are created, stored, used, and exchanged, as well as regarding the integration of user needs in the process of developing these infrastructural concepts.

Regarding object definitions and metadata the main angle is different aspects of the building object due to use, structuring, communication, understanding and access:

- The building object as a multidimensional geo-representation
- The building object as part of an ontological framework or a framework itself due to object-oriented data structuring paradigms.
- The building object as an interface to data or data sets related to buildings due to 2D-, 3D- or 4DGI-potentials.

As means of understanding and integrating user needs a prototyping process based on the "Contextual Design" method is carried out *(Beyer et al, 1998)*. This systems analysis method is based on figurative concepts due to interaction design traditions, and it has successfully been used in the international research project DIVERCITY dealing with modelling virtual collaborative built environments *(Chrisstiansson, 2001)*.

4. THE CITY RENEWAL CONTEXT

A Danish urban renewal context represents numerous aspects of conflicting data-structures, procedures and qualifications. Danish urban renewal procedures has moved from concerning renewal of single buildings towards more holistic concept of renewal of urban areas dealing with ecological, cultural as well as social matters and involving various professions, politicians and residents. And due to the various tasks large amounts of information related to buildings are exchanged.

Based on existing data in various maps and registers concerning population, property and environment city planners locate the renewal area, analyse the impacts, and visualise proposals to citizens and politicians. Chartered surveyors use and update cadastral maps and registers when handling legal and physical affairs related to property transactions. During the building construction processes huge information related to designing the buildings, applying for building permissions as well as updating maps and registers is exchanged between the public authorities, architects, engineering companies and privates. And afterwards databases related to different kinds of supplying and facilities management has to be maintained. Regarding commercial tasks for instance dwellings for sale or rent have to be advertised, houses have to be insured et cetera.

4.1. The user environment

Due to the responses from a survey conducted at the Danish Technical University (DTU) 97% of the architect firms and 82 % of the engineering companies were users of CAD *(Howard, 2001)*. Though only a few data is reused during the information flows between architects, engineering companies and other professionals during the building design and construction processes. 3D-visualisation is emerging within the architectural field though design procedures among architects as well as engineers are conducted due to traditional 2D-concepts *(Erhvervsministeriet, 2001)*. Considering IT-skills among architects and civil engineers in the built environment the IT-training among even newly educated architects are still considered far to low by employers *(Howard, 2001)*.

Despite the fact that various 3D-techniches for decades have been integrated parts of surveying when updating cadastral maps and registers due to handling legal and physical affairs related to property transactions the output has been mainly two-dimensional. Due to the emerging technologies in this field and the rapidly growing market for 3D-models of buildings, cities and landscapes the approach of the Danish surveying profession has begun changing from 2D-mapping to 3D-modelling *(Beck et al, 2002)*. Chartered surveyors are also moving into the building restoration business as well due to a project developing a method for providing precise 3D-models based on interior measurements in order to increase efficiency during the following design and construction processes. Furthermore providing a legal framework for maintenance of 4D building databases could be a potential field of activity for the profession *(Noermoelle, 2001)*.

The typical Danish physical planner in larger municipalities is an architect though the profession counts civil engineers, chartered surveyors and different technicians without academic backgrounds. Due to a survey in 1998 most municipal planning procedures in Danish municipalities were still conducted on paper, as the architect planners traditionally have been very little IT-experienced especially within CAD- and GI-technology *(Bille, 1998)*. Since the implementation of GI and Internet technology has increased remarkable in Danish municipalities *(KTC, 2000)*. However in general the exchange of planning data across authority levels involved in physical planning processes is still poor due to the lack of standardisation concerning object definitions as well as data handling procedures *(Planssystemgruppen, 2001)*. Furthermore the cognition gab between chartered surveyors trained in dealing with maps and geodata and the lack of GI-understanding among the Danish architect city-planners has until now been a barrier to exploiting the potential when dealing with GI-based planning procedures *(Bille, 2001)*.

However regarding the communication potential of 3D-visualisations as means of escaping the flatland of two-dimensional maps and drawings is also gradually being exposed to the built environment *(Chrisstiansson, 2001)* and planners as well as politicians and citizens *(Holmgreen et al., 2001)*. Virtual built environments based on 3D- and 4D-models facilitating knowledge sharing and corporation due to designing and analysing products as well as construction processes are emerging *(Chrisstiansson et al., 2002)*. Two research project at the School of Architecture at the Danish Royal Academy of Fine Arts dealing exemplifies VR-based visualisations as means of developing a shared language facilitating public participation in holistic urban renewal processes. A project web-page concerning the placement of a new royal opera in the Copenhagen Harbour presents a 3D-model, planning documents as well as relevant public news *(Rüdiger et al., 2001)*. In a project dealing with an inner suburb of Copenhagen a 3D-model of the existing environment is the basis for involving residents directly in analysing existing qualities as well as ideas and impacts of the renewal process *(Holmgren et al., 2002)*.

4.2. Multiple use and multidimensional building objects

An extention of the multipurpose Danish public information server into a concept also dealing with multidimensional building-representations based on extending the BBR due to a three-dimensional concept of CIS-CAD is suggested as means of providing a common four-dimensional object oriented framework. Different two-dimensional map-concepts of shape will merge into just different projections of the same 3D-building phenomenon as well as BBR-instructions, conceptual models or metadata aspects in general can be referenced and illustrated by various 2D- or 3D-visualisations *(Fig.5)*. Of particular interest are the different

address concepts dealing with the address co-ordinates respectively in the main entrance door at street level or relating to use-units at different floors. Developing this concept into a 3D-cadastral view also property aspects regarding flats on top of each other et cetera could be represented and visualised in various ways. Access to 3D-models of private houses could be the interface for citizens when submitting applications for building permissions et cetera, which might facilitate owners of real estate providing actual and accurate information.

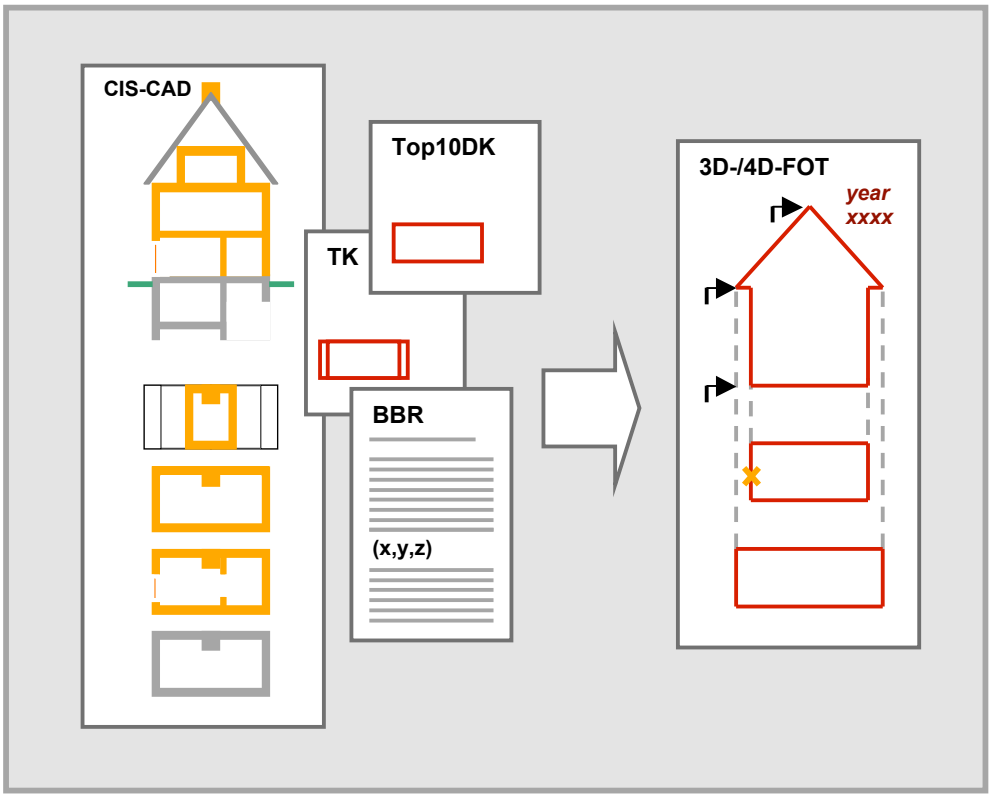

Figure 5: Defining the 4D-FOT building object.

Concerning time as well as geometric appearance the core issue is to provide a common framework for defining and referencing different representations of the building due to various purposes and related to its entire life cycle. So beside the address the minimum elements of the suggested 4D-FOT building object will be the shapes of the ground floor plan as well as the roof plan and at least a main section of the building containing the relevant height information.

6. CONCLUSION

Though efforts have been made to establish procedures supporting sharing and exchange of Danish building data, consensus concerning object definitions has still not been achieved as well as legal aspects remain unsolved.
So far the research undertaken in the project has defined a need for establishing a Danish core data set of 4D-building object. It is stated that from one point of view the emerging multidimensional GI- and VR-technologies within the Danish professional disciplines dealing with design and planning processes is leading to a demand for a core data set of multidimensional building objects as part of the public geo-information infrastructure. The other way around it is argued that the recognition of the building as a four-dimensional geo-phenomenon will provide a valuable reference between different data sets whether

representing buildings in two, three or four dimensions and thereby support a shared understanding among various professions and views. Finally the potential in multidimensional representations of buildings as part of interfaces to various information is emphasised.
The further research will be based on refining this concept due to specific use cases, in which the interaction between actual use, the structuring paradigm, the means of communication as well as the metadata concepts will be considered.

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CV OF THE AUTHOR

Lise Schröder, Ph.D.-student

1990	M.Sc. in Civil Engineering from the Technical University of Denmark
1993-1995	Post graduate studies at Aarhus School of Architecture
1997-1999	M.Sc. in Technology Management in Geoinformatics from Aalborg University
1999	Ph.D.-student at Aalborg University

CO-ORDINATES

Lise Schröder, Ph.D.-student
Aalborg University
Fibigerstraede 11
9220 Aalborg Oest
Denmark
Tel. +45 9635 8080
Fax +45 9815 5775
E-mail lisesch@i4.auc.dk
Website www.gim.dk